VSCL Pegasus UAV General Flight Research Activities: Standard Operating Procedures

Aerospace Engineering Department
Texas A&M University

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INTRODUCTION
This document establishes procedures for safely performing VSCL Pegasus UAV flight test operations. This document identifies the roles, responsibilities, and procedures for test personnel during pre-test, test, and post-test operations.

PROCEDURES
Several procedures are discussed: Pre-test activities, Test activities, & Emergency Procedures (EP).

Pre-test Activities

Flights of the Pegasus UAV will be conducted at the Area of Intended Operations as depicted in Figure 1 below.

Pre-test Notifications
The test director and/or his designated representative will send email notification to all interested parties (per the email notification list maintained by the Test Director) at least 5 hours prior to any potential test activity. Individuals may be added to this list at any time at the discretion of the test director; any person who asks to be removed from this list will be removed and a notation made of the request on the notification file. The initial list includes the following individuals:

Bob Rudder	b-rudder@tamu.edu
David Breeding	bree@tamu.edu
John Valasek	valasek@aeromail.tamu.edu
Rodney Inmon	rinmon@tamu.edu

A follow up message to the same addressees, verifying cancellation or completion of the test and advising of any safety-related issues, will be sent within 5 hours of cancellation or completion of a scheduled test series.

In addition to this email notification the test director or his designated representative will coordinate Riverside Campus scheduling with Mr. Bob Rudder, Riverside Facilities coordination at 979-845-2281. The test director is responsible for ensuring that Mr. Rudder is notified by telephone of the test team's departure from Building 7046 prior to any scheduled tests on the "Active" Runway portion of the complex. The warning and close-out calls are intended to help other users of the Riverside Campus complex and gives Bob Rudder increased flexibility in dealing with the needs of all users. These calls are also the responsibility of the test director, but may be delegated to another team member if the test director deems it appropriate.

Pre-test Briefing
The test director shall conduct a pretest briefing immediately prior to the test reconfirming test objectives, procedures, and emergency procedures. The pilot and ground handlers will ensure that the transmitter, receiver batteries, and ground station computer (if applicable) are fully charged . The test safety officer will ensure that eye protection and disposable ear plugs are available for all personnel and that the fire extinguisher is properly charged.

The test team will review the directions to the test area prior to departure. These directions should be "Enter the Riverside Campus main entry from Hwy 47 (about 1 mile south of the highway 21 and 47 interchange. Enter Riverside Campus on 5th Street. Proceed on 5th Street through a stop sign. When the road terminates at a stop sign, turn left on a road parallel to the apron. Follow this road south and merge onto the south taxiway. As soon as possible, turn right and proceed across the apron to the westbound taxiway. This taxiway crosses Runway 17L/35R and 17C/35C. Proceed to Runway 17R/35L (furthest runway West), stopping before crossing each runway to check for high-speed cross traffic. Everyone should be ready to report these directions to the emergency dispatcher. Students should test these directions out on a "stranger."

Goal is to get emergency responders to a victim fast -- even if they've never been to Riverside Campus before.

In an emergency situation, the flight safety officer will go to the main Riverside entry, meet the emergency responders, and direct them back to the test site. This will save valuable time in emergency situations.

The test director hands out radios to support the flight test. The pilot checks the battery level and sets the frequencies on the hand-held air band radio (see Table 1). Observers, ground station operator, and test director ensure that hand-held FMRS radios are operating properly and have adequate battery life remaining for the test. The test director gives the primary and backup channels of the day.

Table 1: Air Band Radio Frequencies and contact info for Easterwood ATC (KCLL)

CTAF:	118.5
UNICOM:	122.95
ATIS:	126.85
WX ASOS:	PHONE 979-846-1708
EASTERWOOD GROUND:	128.7 284.7 [0800-2100]
EASTERWOOD TOWER:	118.5 284.7 [0800-2100]
EMERG:	121.5 243.0
WX AWOS-3 at RWV (18 nm W):	118.35 (979-567-6784)

Weather Check

Upon arrival at the test site the test director and test safety officer shall verify the weather conditions are within operational limits using an anemometer. Flight testing will only be done during daylight hours, with stable weather (Visual Meterological Conditions - VMC), and with wind limits 14 MPH both on the surface and/or as measured above ground and gust limits of no more than 5 MPH. Maximum altitude and range boundaries must be flown so there is always visual contact by the pilot. Riverside weather can be checked at the following web site: http://www.srh.noaa.gov/forecast (search on "College Station, TX" for current weather conditions and forecasts).

Unmanned Aircraft (UA) Inspection

The pilot and Test Safety Officer will check the helicopter vehicle and ensure, per the pre-flight check-list that:

Assembly hardware is properly installed, removable hatches secured, and quick-access hatches are operable

All assembly tools and "remove before flight" items have been stowed in storage container

Flight controls rigged properly

Engine controls set correctly

Tires, landing gear, and steering are sound and secure

Radio is properly programmed for intended operations (including autopilot as needed)

Battery levels are adequate for proposed test duration

Electrical power fail-safe switching is operable

Autopilot fail-safes and disengagement systems are ready

Airborne telemetry is transmitting and being received at ground control station

Aircraft Center of Gravity (CG) is within design limits or at specific location (as needed)

Test Area Visual Survey

The wind speed and direction wll be observed to be within the test limits. All observers will be dispersed to their remote observation stations. When the Test Safety Officer (TSO) determines test operations may commence, test team members may prepare the aircraft for flight testing.

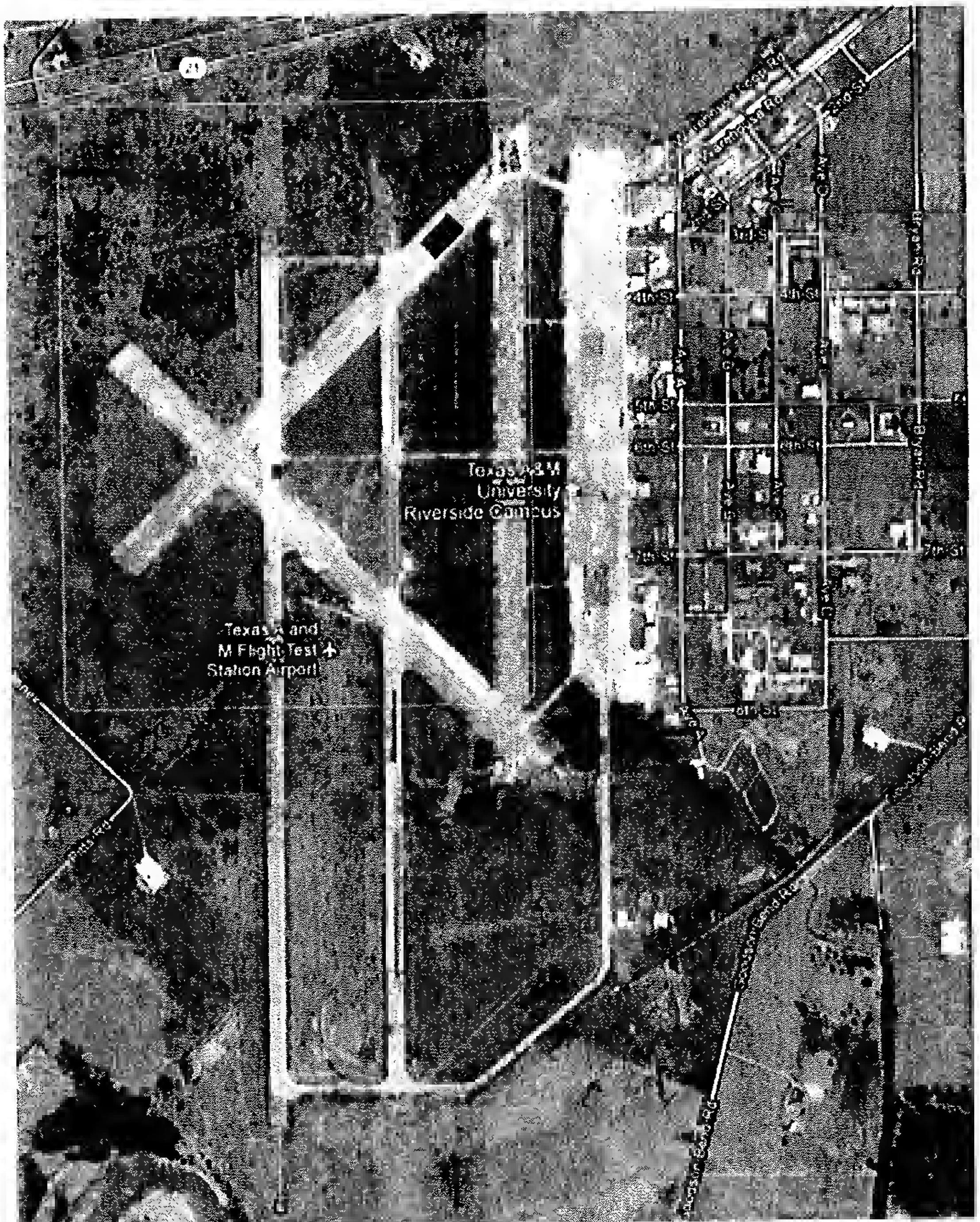

Figure 1. Riverside Campus Flight Test Facility (83TX). Area of Intended Operations is marked in green. Vehicle preparation and ground station setup area is marked in red.

Prior to each day's testing, the project group will line up and police the runway cross area for loose debris, metal objects, concrete pieces, etc., that might pose increased risk.

Test Configuration Buildup and Engine Start

Ground team members unpack and set up: anemometer, support and safety equipment, fire extinguisher, Pegasus aircraft, and fuel from the transportation vehicle and move it to the vehicle preparation area. The test safety officer fuels the plane under the constant supervision of the designated fire extinguisher attendant. The aircraft is set-up facing into the local wind in an area suitable for take-off. The test safety officer and pilot independently inspect the propeller. The pilot turns on the transmitter and verifies throttle and idle slider are set to minimum positions. The ground station operator powers on the ground station (if applicable) and all data acquisition equipment (if applicable). One of the ground handlers puts the aircraft power switches to the "run" position.

- Pilot performs preflight radio check and sets controls and trim to take-off position.
- All personnel except the ground handlers and test safety officer move away from the aircraft to a distance of at least 30 ft from the aircraft during engine start.
- Pilot verifies that throttle control is in idle position and both ground handlers hold the leading edges of the wing on both sides of the aircraft firmly in both hands. The test safety officer verifies the engine ignition is in the "off" position and steps between the aircraft tailbooms. The test safety officer sets the engine choke and applies the electric starter for 5 seconds. The test safety officer clears the choke, sets the ignition to the "run" position, and applies the electric starter until the engine starts.
- After the engine starts, the test safety officer slowly backs away from the propeller towards the rear of the aircraft. When the test safety officer signals readiness, the ground handlers slowly roll the aircraft forward until the test safety officer is clear of the aircraft tail.
- The pilot adjusts the throttle to idle and allows the engine to reach operating temperature. The pilot verifies the engine is running smoothly and the carburetor needles are set properly by listening to engine operation.
- The pilot deflects the control surfaces and monitors control surface response for correct deflection magnitude and direction.
- The pilot performs a full-throttle engine runup and engine-on radio range check, then returns engine to idle.
- The ground handlers release the aircraft when directed by the pilot.

Radio Range Ground Check

Prior to flight test, a range test will be conducted to assure the radio link can be maintained over the distances expected during operations. The radio transmitter and receiver range will be verified first with engine off. With all radio/ground station equipment on, the pilot with transmitter and/or ground station will move to a distance of ~100 ft (pilot's discretion) and cycle the elevator, aileron, and rudder controls with the transmitter output attenuated. Ground handlers will verify the proper operation of the control surfaces. If there are any problems, corrective actions must be taken prior to the start of testing. If the autonomous control system is to be used, telemetry radio transceiver RSSI must be at -76 dBm or higher. Testing may commence only if all indications on the ground station are normal.

Test Activities

- All personnel will maintain a distance of at least 30 ft from the aircraft at all times during flight.
- Pilot performs normal take-off as outlined by the test team
- Test conditions are flown and test director records notes and communicates with the pilot to assure efficient test operations.
- Ground handlers, test safety officer, and test director remain vigilant to any unauthorized runway incursions, air traffic issues, and any wind changes and communicate unsafe situation(s) to the pilot.
- Test safety officer remains vigilant to any health and safety issues.

- After testing is complete, the pilot sets up an approach into the local wind. The landing maneuver is performed.
- Immediately upon touch down pilot shall set engine to idle. The pilot will then taxi the aircraft back to the vehicle preparation area or stop the engine at his discretion.
- **After the aircraft comes to a complete stop,** the test director leads the test team to the aircraft. The test safety officer switches the ignition to the "off" position.
- Ground handlers inspect aircraft for damage.
- Ground handlers return the model to the flight preparation area for next test run.
- Ground station operator downloads test data from aircraft data logger (if applicable).
- Test team reviews test results and the test director determines next test configuration based on test matrix.

Emergency contect Information

All personnel help in securing medical attention. TAMU Emergency Services accessed by dialing 9-911 on the TAMU phone system or by direct dialing at 845-2345. Dial 911 to access Brazos county emergency services. University Hospital's phone number is 845-1511.

Be Prepared to Provide Critical Information:

Caller's Name:
Location:
Building Name:
Building No:
Nature of the Emergency:
Name & Number of Victims:

TAMU Emergency Phone Numbers:

9-911 on TAMU phone system OR 979-845-2345

Emergency Procedures (EP):

1 Personnel come into contact with a spinning propeller/impeller:
   1.1 TD Calls "STOP ENGINE – STOP ENGINE".
   1.2 PILOT moves the throttle control stick on the transmitter to the "IDLE" position, moves the trim slider to "ENGINE KILL" position (for gas powered aircraft), and replies "ENGINE STOPPED" when the command has been acknowledged and completed.
   1.3 If the incident occurs during runup, GROUND HANDLER ONE switches ignition to "OFF" position.
   1.4 If the autonomous control system is in use, PILOT overrides autonomous controller using transmitter, moves the throttle control stick to the "IDLE" position, and moves the trim slider to "ENGINE KILL" position.
   1.4 All personnel help in securing medical attention (see emergency contact information above).

2 Aircraft is or becomes uncontrollable:
   2.1 PILOT calls "LOSS of CONTROL – LOSS of CONTROL" and kills engine.
   2.2 TD notifies all Team Members and Observers of situation.
   2.3 (Manual operation) PILOT adjusts aircraft for landing and lands in remote area. If loss of control is total or if aircraft becomes unresponsive to pilot commands but maintains trimmed flight beyond the AIO, the pilot shall seek to terminate the flight by commanding the engine to shut down.
   2.4 (Autonomous operation) PILOT will override autonomous flight control system using failsafe switch on transmitter and attempt to bring vehicle under control. PILOT will then adjust aircraft for landing and land in remote area. If loss of control is total or if aircraft becomes unresponsive to pilot commands but maintains trimmed flight beyond the AIO, the pilot shall seek to terminate the flight by commanding the engine to shut down. Note that the autopilot has a fail-safe built-in so that if contact is lost with the ground station, the aircraft will automatically proceed to a designated waypoint and orbit until communications are reestablished or the aircraft runs out of fuel.
   2.5 GROUND HANDLERS and TD bring aircraft into a safe state.
   2.6 GROUND HANDLERS and TD inspect the aircraft for damage.
   2.7 Testing is stopped until the aircraft is repaired.

3 A Fire is Observed in the Area of Intended Operations:
   3.1 Person first noticing fire, calls "FIRE - FIRE". All personnel clear the area. If fire is observed on model, PILOT executes immediate landing in remote area clear of personnel.
   3.2 TSO evaluates use of fire extinguisher and assigns closest person to the extinguisher (PILOT, GH or TD) to extinguish the fire.
   3.3 If fire is uncontained, TSO radios or calls fire department (see emergency contact information above).
   3.4 TSO calls fire department on cellular phone. TSO is responsible to ensure that the fire department is inserted as a redial number during all flight activities.
   3.5 All test personnel move 75 feet from aircraft.

Post Test Activities

- The test article is prepared in reverse of pre-test activities. Unused fuel will be removed from the aircraft under the constant supervision of the fire extinguisher attendant prior to transport.
- Inspect the test area for debris and for all test equipment
- Battery charging
    - NiCd and NiMHs – follow manufacturer procedures
    - Sealed Lead Acid – follow manufacturer procedures
    - LiPo – follow manufacturer charging, discharging, and storage procedures

- LiFePO4 – follow manufacturer procedures
- Lead Acid (used with starter) – charged by Test Safety Officer using battery charger's user's maunual recommendations (stored at FML in Building 7046) . Always use a jumper on negative terminal, and battery.

DEFINITIONS

Test Director (TD): Central test authority with overall responsibility for all aspects of test. Can take any action not restricted by test rules to safeguard equipment.
Test Safety Officer (TSO): Advise test director of hazardous situations and suggest corrective actions. Responsible for fueling aircraft and starting engine.
Pilot: Responsible for controlling the aircraft.
Safety Observer: These individuals maintain direct line-of-sight contact with the unmanned aircraft and scan for air traffic that may pose a collision threat; they are responsible for secondary guidance to the Pilot to aid in collision avoidance.
Ground handlers: Responsible for assembling and inspecting the aircraft, restraining the aircraft during engine starting and runup, and recovery of aircraft and support equipment.

FLIGHT CHARACTERISTICS

The Pegasus aircraft is a student-designed and built aircraft using a conventional configuration and construction similar to that used in composite homebuilt aircraft. Though the aircraft is unproven, significant engineering resources have been devoted to ensure the Pegasus aircraft has sedate and predictable flying qualities in its stable configurations. When operating in low, neutral, or negative static stability configurations, extensive care is taken to ensure the stability augmentation system works properly before flight. While vehicle design and construction may be sound, safety and reliability of operation relies on proper maintenance procedures. As a prerequisite for any flight, a successful flight readiness review and pre-flight test briefing will be conducted. In addition, an airworthiness inspection will be performed by both the Test Director and the Pilot prior to any test.

All aircraft may prove difficult to fly, especially during slow flight and in suddenly-changing weather conditions. As such, only qualified RC pilots will be engaged to perform test flights. Pilots must have extensive experience flying giant scale RC aircraft. All pilots must be checked out and approved prior to certification as a VSCL test pilot by the Test Director. All operations shall observe procedures approved by the SRB.

PROJECT IDENTIFICATION SECTION

Project Name: VSCL Pegasus UAV General Flight Research Activities

TEES Project Number: 32525 – B4280
TEES Proposal Number: 12 - 0380

Project Description:
This project safety analysis covers flight research activities conducted by the Vehicle Systems and Control Laboratory (VSCL). VSCL personnel will conduct flights of unmanned fixed-wing aircraft controlled either by a qualified RC pilot or by an autonomous control system with a qualified RC pilot standing by. Research flights will be conducted for the purposes of system identification, dynamics, control, aerodynamics, structures, and sensors research. Flight activities will involve the principle investigator (Dr. John Valasek) as well as VSCL graduate and undergraduate student researchers. It is anticipated that flight experiments, conducted for the variety of purposes described above, will lead to advancements in a broad array of aerospace fields that will be published and used to secure outside research funding as applicable.

Principal Investigator:

Name:	Dr. John Valasek
Department/Division:	Department of Aerospace Engineering
Office Location:	719C H.R. Bright Building
Office Phone Number:	979-845-1685
Email:	valasek@tamu.edu

Researchers:

Name:	Dr. John Valasek
Department/Division:	Department of Aerospace Engineering
Office Location:	719C H.R. Bright Building
Office Phone Number:	979-845-1685
Email:	valasek@tamu.edu

Name:	Andrew Beckett (Graduate Student)
Department/Division:	Department of Aerospace Engineering
Office Location:	7046 Rm 105
Office Phone Number:	N/A
Email:	drasnor@tamu.edu

TBD

Location of Project Facilities:

Building No:	0353
Building Name:	H.R. Bright Building (HRBB)
Room No:	012

Building No:	7046 (Riverside Annex Campus)
Building Name:	Building 7048
Room No:	all

Project Duration:

Start: January 2012

End: To be determined

REVIEW & AUTHORIZATION SECTION

The attached Project Safety Analysis has been reviewed by the undersigned. Any major modifications of equipment or changes in procedures will require additional review by the Departmental Safety Committee, and/or the Departmental Safety Officer, and the Department Head. In executing this work, you must abide by the Safety Procedures of the Department and University and must inform the Departmental Safety Officer of any changes in personnel or operetions outside these procedures.

John Valasek — 11 FEB 12

Faculty/PI: Dr. John Valasek — Date:

2/13/12

Department Head: Dr. Dimitris Lagoudas — Date:

Rody — 13 FEB 2012

Dept. Safety Officer: Mr. Rodney Inmon — Date:

D. Breeding 22-Feb-2012

ENGINEERING SAFETY OFFICE 2012 FEB 22 RECD

Director, Engineering Safety Dr. D. C. Breeding — Date:

C. Informational Copies

Please send a copy of your final approved PSA document to the following TAMU Departments, for their information and use. Any comments or concerns will be conveyed to the PI and to the Office of Engineering Safety before initiation date of the proposed project.

TAMU Environmental Health & Safety Department (EHSD) Date:
Mail Stop: 4472 TAMU

(A copy of the approved PSA is provided to EHSD for their information and use. EHSD will review and keep on file, and notify Engineering Safety if any additional concerns are noted.)

TAMU Office of Facilities Coordination, MS 1369 Date

(To accompany requests for new space assignments or requests for use of sites at the Riverside Annex Campus or other outdoor sites.)

Other Date:

STRATEGY SECTION

Purpose of Project Safety Analysis:

PSA provides the Principal Investigator with the opportunity to review the environmental health, safety and security aspects of the research project to be undertaken, to identify known and potential hazards, to assess risks, and to select and implement necessary protective controls. This will help protect the researchers, graduate students, and staff involved with the project, reduce risk, ensure compliance, and conserve environmental resources, and protect facilities.

The purpose of this PSA is to document analysis performed and safety measures taken prior to flight testing of unmanned helicopter vehicles belonging to the Vehicle Systems and Control Laboratory (VSCL) at Texas A&M. Professor John Valasek is the supervisor of VSCL and will maintain primary responsibility for oversight of flight activities.

Scope:

All Principal Investigators shall file a written report on the safety analysis of each research project prior to the initiation of that exercise. The Project Safety Analysis (PSA) shall identify potential hazards and assess risks by the use of system safety analysis techniques, and shall detail the engineering and administrative controls that will be necessary to reduce risk to acceptable levels for the researchers, graduate students, and staff as well as the occupants of the building and the environment. The PSA will identify the costs, and the source of adequate funding, to implement necessary controls. It will identify necessary personnel training needs. The PSA will identify a plan for ultimate disposal of leftover equipment, materials and wastes, and the decontamination & clean up necessary to render the facility safe to reassign and reoccupy.

The Vehicle Systems and Control Laboratory engages in a wide range of flight test projects spanning flight controls and estimation to aerodynamics and structures research. To this end, the lab operates the Pegasus UAV, a fixed-wing aircraft with a wingspan of 12 feet and take-off gross weight of up to 84 lb. All flight test procedures consist of pre-flight ground safety and operational checks, flight operations, and post-flight ground safety and operational checks. Flight testing will be performed in accordance with manufacturers' specifications regarding gross weight, CG envelope, etc. Vehicles will be equipped with autonomous control systems but will maintain the capability for control by a ground-based pilot in the event of control system malfunction. Instrumentation will include live air data, GPS, and telemetry from a variety of on-board inertial sensors to assess operational performance. Fuel consumption will be measured indirectly post-flight during ground servicing.

Extent of Applicability:

Recognizing that no activity is without some degree of risk, and that certain routine risks are accepted without question by the vast majority of persons (for example: machine shops that do not handle hazardous materials, cars used for personal transportation, etc.) the applicability of this analysis has been limited to those academic research projects that involve hazards not routinely encountered and accepted in the course of everyday living by the vast majority of the general public.

Assistance in Conducting PSA

The Office of Engineering Safety is available to work with the Faculty/PI and research staff to identity hazards associated with the project, assess risks, and to identify necessary protective control measures.

The analysis of a project which involves only hazards of a type and magnitude routinely encountered and accepted by the public will require justification which can be referenced to a recognized source.

VSCL Activities & Scope

The research conducted by VSCL will involve autonomous aircraft flights for a variety of flight controls, state estimation, aerodynamics, and structures research. Flight tests will be carried out by the VSCL team led by Dr. Valasek. Each team member will be assigned specific responsibilities and will be briefed on safety issues prior to each flight as discussed in the hazard analysis and validated by the Safety Review Board (SRB). Appropriate safety equipment will be provided to all team members and they will be instructed in its use at the Flight Readiness Review (FRR) and at pre-flight briefings. The attached VSCL Pegasus UAV General Flight Research Activities Hazard Analysis Plan (HAP) details the hazards associated with these tests and spells out the actions taken to mitigate the risks to both personnel and property involved in the testing. The flight testing is to be done at the convergence of "Active" Runway 17R-35L and the crossing runways at the Riverside campus (Figure 1). This location affords the largest paved landing area (hard apron) in the case when an emergency landing is required and is situated next to a large mowed grass area (soft apron). Generally, all flight

tests will be limited to an altitude below 400-feet Above Ground Level (AGL) and within line-of-sight of the pilot and observers not to exceed 1-mile laterally. In general, the Area of Intended Operations (AIO) measures 2000-feet wide by 3,000-feet long. This AIO includes the approximate landing pattern and extent of the envelope expansion test area. Flights planned for altitudes exceeding 400 ft or beyond visual range require a supplement to this PSA, SOP, and an FAA Certificate of Authorization.

VSCL personnel will coordinate and schedule activities at the Riverside Annex Campus and use of the runway surfaces, in advance, with the TAMU Office of Facilities Coordination and with the FOC Facilities Coordinator for the Riverside Annex Campus. FOC requires that Riverside facilities use requests from the Engineering Proram be accompanied by a copy of the final, approved Project Safety Analysis (PSA) specific to the referenced project.

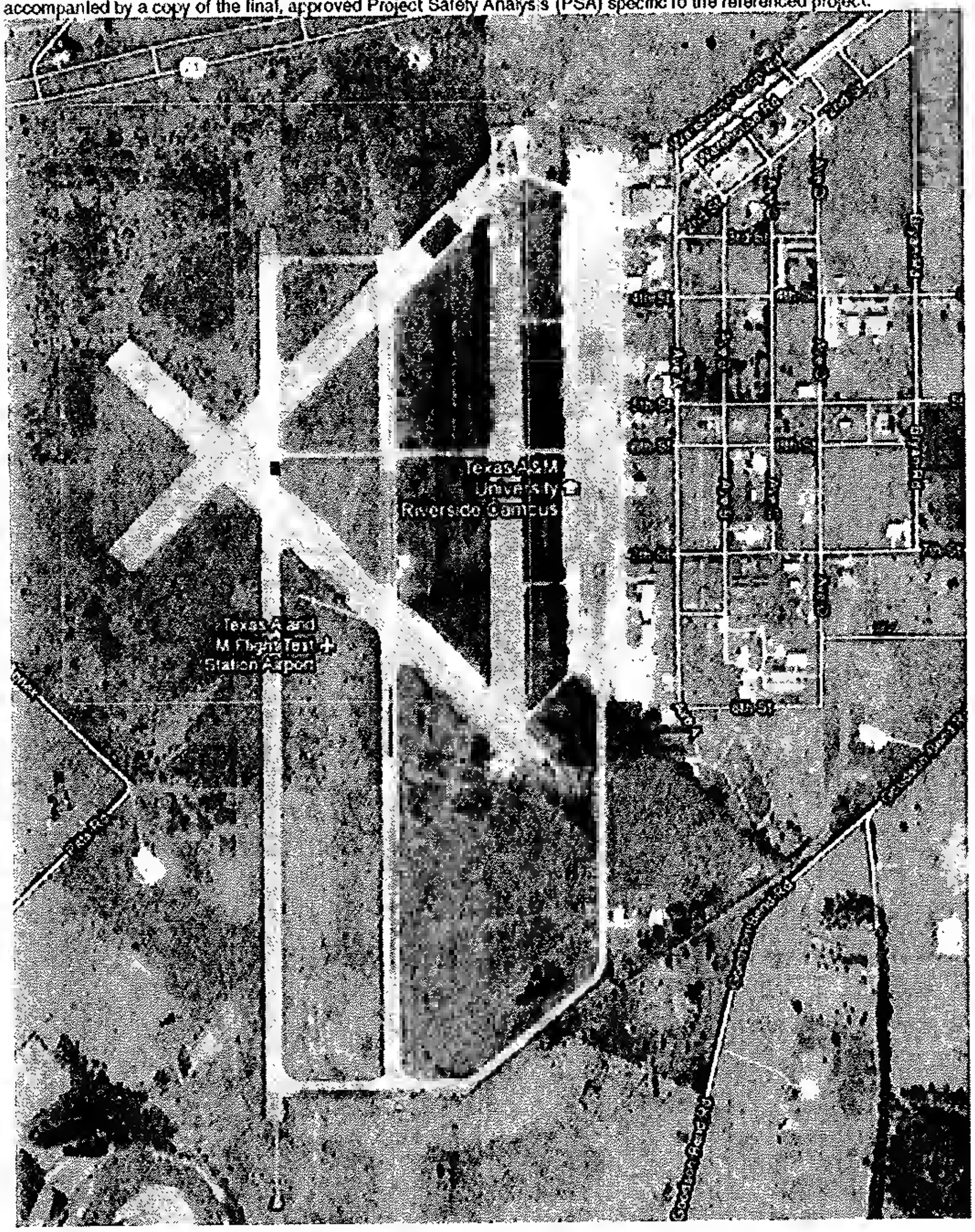

Figure 1. Riverside Campus Flight Test Facility (83TX). The Area of Intended Operations is marked in green and the vehicle preparation area is marked in red.

PROCEDURE SECTION

I) Apperatus Used in the Project

A) Equipment Used in the Experiment

The Vehicle Systems and Control Laboratory meinteins one Pegasus autonomous aircraft owned and operated by the Department of Aerospace Engineering, Texas A&M University / Texas Engineering Experiment Station (TAMU/TEES) and plans to build another three aircraft over the course of 2012. A detelled description of the Pegasus aircraft is below:

TAMU Pegesus Type 0

The Pegasus Type 0 is a scratch-built fixed-wing gasoline-powered aircreft using the conventional twin-tailboom pusher-propeller configuration. Pegasus has a dry weight of 64 lb and a maximum gross takeoft weight of 84 lb. The powerplant is a German-manufactured 3W 85Xt 85cc two-stroke gasoline engine which develops ~9 HP with a 24" 3-blade glass-filled carbon fiber propeller at ~6000 rpm. Fuel is 100LL avgas blended with full-synthetic model aircraft two-stroke oil in 32:1 ratio. Pegasus was designed entirely by students at Texas A&M University with consultation from qualified experts in the autonomous aircraft Industry and built by students under the supervision of a qualified FAA airframe and powerplant mechanic. The aircraft is constructed using proven moldless composite sandwich techniques and composite vacuum bagging techniques. All materials used are aircraft-grade. Avionics power is provided by a pair of 5-cell 2200 mAh NiMH battery packs and ignition power is provided by a single 5-cell 2200 mAh NiMH pack. Installed payloads can be powered by an optional pair of 4000 mAh 5-cell LiPo battery packs. Primary flight control is provided by a 9-channel JR/Spektrum 2.4GHz direct-sequence spread spectrum radio. All control surfaces ere double-redundant and are driven by high-torque digital servo actuators. The propeller arc is marked clearly on the tail booms for added safety while the engine is running.

Autonomoue Control Systeme

The Pegasus UAV is optionally equipped with autonomous flight control systems. VSCL uses several autopilots for its vehicles and Pegasus is designed for compatibility with all of them. These autopilots include the Cloud Cap Technology Piccolo Plus commercial autopilot, the DIYDrones ArduPilot Mega universal open-source autopilot, the DIYDrones PhoneDrone Android ADK-based autopilot, and the Gumstix RoboVero automation controller. All of the above autopilots feature one or more microprocessors coupled with GPS, inertial sensors (gyros and accelerometers), and magnetometers. Standard stabilization loops and waypoint-following controls are Implemented. A ground station computer operates as the command and control station during flight, and link with the aircraft is accomplished through the use of a 900MHz wireless transceiver manufactured by Digi Inc. for the ArduPilot Mega, PhoneDrone, and RoboVero or manufectured by Cloud Cap Technology for Piccolo Plus. Dual redundant batteries are used for powering the autopilot and servo actuators. Pegasus may be flown manually at any time with any system. Several failsafes are in place when operating in autonomous mode. If at any time the vehicle loses link with the ground control station, the on-board autopilot

optionally loiters in an orbit about a pre-configured fail-safe until link is regained or the aircraft exhausts its fuel. If link is not re-established before the aircraft runs out of fuel, the autopilot attempts to maintain airspeed in a gliding descent and landing. When the autopilot is in use, the pilot may override control at any time and manually control the vehicle. Should the vehicle attempt to fly beyond the area of intended operations (AIO), a flight termination system can be employed to kill power to the aircraft.

Though Pegasus is designed for long endurance and range, VSCL maintains strict line-of-sight operations in Class G and Class E airspace.

Integral to VSCL's flight testing operations are the ground control station and communications links. The ground control station includes a laptop computer for vehicle status, health monitoring, and data logging as well as a 900MHz telemetry transceiver for receiving telemetry and transmitting high-level system commands to the vehicle. The ground station may also include a video monitor for receiving and displaying on-aircraft video telemetry if the vehicle is so equipped. Ground safety observers and the pilot are the only means of providing the "see and avoid" function to maintain safe clearance from other aircraft. If vehicle deviations are required in order to avoid air traffic when autonomous flight is performed, such maneuvers may be commanded either via the autonomous control system through the ground station, or through the emergency piloted flight capability. The pilot and observers maintain continuous voice contact with hands-free commercial radios, and the pilot has a hand-held air band radio to listen to local air traffic control broadcasts, attempt to contact air traffic that may approach the AIO, and alert local air traffic control of any hazards posed by operation of the helicopter vehicle. All vehicles are designed only to support daylight, visual flight rules (VFR) operation. Flight into clouds, beyond line-of-sight, or in weather above the operational minimums is prohibited per VSCL operating procedures. Any vehicle flown into Class E airspace will be equipped with a transponder and certified instruments, but operations are still limited to line-of-sight.

Support Equipment:
- Fuel container
- Fuel transfer equipment
- Starter and 12/24-V lead-acid battery
- Unmanned aircraft storage container
- Unmanned aircraft assembly tooling

Ground Control Station:
- R/C radio (JR) operating @ 600 mW power level on 2.4 GHz ISM band
- Telemetry monitoring station and Ground Station Computer - laptop running ground station software (autonomous operation only)
- Telemetry radio operating @ 60 mW power level on 900 MHz ISM band

Operational and safety equipment:
- Anemometer (Kestrel 3000 or Windtronic 2) and tripod
- Hand-held VHF Air band radio (pilot)
- Hand-held FRS radios for crew (test director, test safety officer, ground station operator, and observers)
- Power generator
- Video camera and tripod
- Trailer/Shelter

Fire Extinguisher
First Aid Kit
Flight line barrier
Guest barrier
Eye protection (at all times on flight line or within 10-feet of aircraft)
Hearing protection (when within 30-feet of running motor)
Sun/weather protection (as needed)
Oil-absorbent material

B) Experiments Performed In the Project

Experiment	Responsible	Experiment Objective
Vehicle Maintenance and Check-Out Flights	Test Director	Several flights (5-10) will be performed to verify aircraft handling qualities and characterize vehicle performance. Flights will last less than 10 min and will not exceed 400 ft in allitude. The vehicle will be flown under manual control in a racetrack pattern within 1500 ft of the flight test crew. The goal of these flight experiments is to familiarize the pilot with aircraft handling characteristics and verify engine and fuel system performance. While the vehicle is on the ground, engine tests will be performed to verify proper development of power and throttle response. Engine cylinder head temperature will be monitored via telemetry at all times. Lateral and longitudinal control surface inputs will be provided while on the ground to ensure proper response prior to flight. After landing, the aircraft must come to a complete stop before any personnel approach the vehicle. During all flights, the vehicle will maintain at least 30 ft of distance at all times from all personnel.

Experiment	Responsible	Experiment Objective
Data Collection Flights	Test Director	Several flights (~10) will be performed to collect data from on-board sensors (GPS, gyros, accelerometers, and magnetometers). This data will then be used to develop simulation models which will be exercised later for research purposes and used in the development of autopilot control laws. These flights will be performed under manual control. Flight phases will consist of: takeoff, climbout, racetrack pattern w/ dynamic excitation maneuvers on the upwind leg, approach, and landing. The same flight restrictions described in Vehicle Maintenance and Check-Out Flights will apply here. During all flights, the vehicle will maintain at least 30 ft of distance at all times from all personnel.
Autonomous Control System Performance Test and Evaluation Flights	Test Director	The primary purpose of these flights will be to test performance of the autonomous control systems (autopilots) in flight. These flights will test the operation of each ot the following flight components: heading, altitude, airspeed, and bank angle command and hold; waypoint and erea-of-interest navigation, autonomous takeoff, and autonomous landing. Other pre-defined maneuvers may be added to this list as determined by the test director. Autopilot interaction with the ground control computer will also be tested during these flight experiments. The pilot will be standing by during all autonomous operations and will be ready to take over control of the aircraft if needed. The same flight restrictions as described above will be used on the first several flights in this category. Once all autonomous features are verified, flights of up to 60 minutes are permitted. Pilot-in-command time will be less than 10 minutes at a stretch to avoid operator fatigue. During all flights, the vehicle will maintain at least 30 ft of distance at all times from all personnel.

Experiment	Responsible	Experiment Objective
Machine Vision Relative Navigation Experiment	Test Director	A research project conducted over the course of CY 2012 requires integration of an experimental flight control law and machine vision sensor with the DIYDrones ArduPilot Mega autopilot. The experimental control law allows the eircraft to track a point of interest on the ground using only relative position information collected with the machine vision sensor. The flight test will meke use of the configurable flight mode features on ArduPilot to ellow the pilot to switch between manual control, waypoint-based navigation, and experimental machine vision relative navigation. The flight test procedure consists of takeoff under manual control, manual or waypoint-based autonomous navigation to the experimental insertion point, confirmation of acquisition of point of interest, manual switch to machine vision relative navigation mode, autonomous orbit of point of interest, automatic return to waypoint navigation mode upon loss of point of interest, repeating insertion and tracking as needed, and manual approach and landing. Flights will last no longer than 60 minutes at a maximum altitude of 400 ft. Pilot-in-command time will be less than 10 minutes at a stretch to avoid operator fatigue. As with all flights, the vehicle will maintain at least 30 ft of distance at all times from all personnel.

Any flights that do not qualify under one of the above categories will need to be approved under another Project Safety Analysis document.

C) Chemicals Used in the Research Project:

High-octane leaded aviation gasoline with 2-cycle synthetic lubricating engine oil additive

Required chemical inventory current and posted?

Yes.

Material Safety Data Sheets (MSDS)?

Yes. MSDS sheets are posted in the master MSDS binder at Riverside Campus, building 7046.

All stored chemicals segregated by Hazard Class?

Yes. Fuel and oil are the only chemicels that will be used during flight test operetions, and will be kept in e fuel storage locker at Riverside Campus, building 7046.

II) Analysis of Potential Hazards

A) List all Physical Hazards That May Cause:

1. Abrasions – contact with spinning propeller blades. See Hazard Analysis Plan (HAP).
2. Burns – contact with motor or engine after operetion. See Hazard Analysis Plan (HAP).
3. Poisoning – inhalation, ingestion, or skin contact with fuel. See Hazard Analysis Plan (HAP).

B) List all Chemical Hazards

Flammebles

High-octane leaded aviation gasoline with 2-cycle synthetic lubricating engine oil additive

Toxins

High-octane leaded aviation gesoline with 2-cycle synthetic lubricating engine oil additive

C) Biological Hazards

None

D) Secure, Segregated Chemical Storage:

Locations: Riverside Campus Building 7046, Inside fuel storage locker
Quantities: 1 gallon
Authorized Person(s) Accessing the Chemicals: Dr. Valasek, Cecil Rhodes, Rodney Inmon, graduete, or undergraduate students working on the current flight test

E) Hazardous Weste Disposal

- Building 7046 – A petrochemical disposal drum with funnel and flame arrestor is on-site for disposal of contaminated fuel or oil.
- Building 7046 – A drum of oil-absorbent material with scoop is on-site for cleanup of accidental/incidental oil spills. Oil-absorbent material adequate for cleanup of at least 4 L of spilled fuel is included in the flight test equipment.

F) Monitoring and Detection

N/A

G) List all necessary Personal Protective Equipment (PPE)

Long Pants	Yes
Long Sleeved Shirts	No
No Shorts, No Skirts	Yes

Closed-Toed Shoes	Yes
Aprons/ Lab Coats	No
Goggles/Face Shields	Yes, for ground handlers and TSO
Gloves	Yes, for TSO
Respirators	No
SCBA	No
Hearing Protection	Yes, for ground handlers and TSO
Other...	

H) Personnel Training Needed for Specific Hazards

All participants in the VSCL flight research program must complete TEES training courses 811010 "TEES Laboratory Safety Course" and 811013 "TEES Shop & Tool Safety Course" and read and be familiar with the Standard Operating Procedures (attached). Fire extinguisher training is also required for all test team members. Extreme heat training material will be distributed to the test team. Test Director and Test Safety Officer must read and be familiar with fuel MSDS.

III) Potential Accidents and Responses

A detailed description of potential accidents and responses can be found in the attached Hazard Analysis Plan (HAP).

A) Utility Failure

Utility:	Planned Response (SOP's):
Electricity	N/A
Gas	N/A
Air	N/A
Vacuum	N/A
Hot Water	N/A
Cold Water	N/A
Ventilation Hood	N/A
Room/Lab Ventilation	N/A

B) Leaks and Spills

MSDS Available:	Yes
Spill Kit Available:	Yes
PPE Available:	Yes
Containment Procedures:	Yes
Disposal Procedures:	Yes
Personnel Training:	Yes

Disposable gloves and oil-absorbent material are included in the flight test kit for containing end cleaning up leaks and spills. In the event of a crash, the vehicle and any vehicle debris will be promptly removed from the flight test area and any spilled fuel cleaned up.

(In the event of fuel leakage, the fuel typically evaporates so quickly that there is nothing to be done except let it evaporate. The quantities stored and used are so small that this is not anticipated to be a serious hazard. Large 2-stroke engines drip small quantities of unburned oil additive on the runway which, while not posing a significant hazard to personnel, must be cleaned up to prevent damage to the runway surface.)

C) Equipment Failure

Contingencies for failure of UAV control equipment is dealt with extensively in the SOP and HAP documents (attached).

D) Fire Prevention

Fire Extinguisher Locations: With flight test team at all times.
Fire Extinguisher Type: Dry ABC for ground fires, Halon ABC for aircraft fires.

Aircraft fires involving lithium-based batteries are class D, but due to the small quantities of metal involved the class D fire quickly devolves into a class AB fire.

Building Emergency Evacuation Plan: N/A, for field work site
Evacuation Routes: N/A, for field work site
Emergency Response Procedure: Covered extensively in SOP and HAP.
Incident Reporting and Notification Procedure: Covered extensively in SOP and HAP.

IV) Equipment Labels

A) Utility Shut-offs labeled:

Electricity	N/A
Vacuum	N/A
Gas	N/A
Air	N/A
Hot Water	N/A
Cold Water	N/A

B) Identify all necessary Warning Signs:

Equipment	N/A
Instrumentation	N/A
Utilities	N/A
Personal Protective Equipment	N/A
Reagent Bottles	N/A
Secondary Containers	N/A
Refrigerators and Microwaves	N/A
Chemical Storage –	Fuel storage locker is properly labeled.

*Emergency Contact Information (*ECI*)
Currently posted on the door to Building 7046.

V) Noise

Will the project/ generate excessive noise? Yes, but only when in close proximity to a running engine.

If yes, anticipated dBA is: ~100 dBa

The Pegasus UAV is equipped with a low-profile muffler and produces a noise signature similar to that of a commercial gas chainsaw. If the engine noise level

is suspected to be excessive, the College of Engineering Safety Office is available to monitor sound-levels and noise exposures as appropriate. **Note that personnel will be in close proximity to a running engine only for short periods of time, and thus no hearing damage from long-term exposure is possible.**

Type of hearing protection provided: OSHA-approved over-ear hearing protection is available and will be used by ground handlers and test safety officer. Ear plugs will be available and used by all other personnel within 100-feet of a running engine.

VI) List all Personnel Training Needs

Laboratory Safety Training	Yes (all VSCL personnel)
Hazard Communication Training	Yes (all VSCL personnel)
Shop & Tool Safety Training	Yes (all VSCL personnel)
Hands-On fire Extinguisher Training	Yes (all VSCL personnel)
Standard Operating Procedures (SOP)	Yes (all VSCL personnel)
Safe Work Practices (SWP)	Yes (all VSCL personnel)
Extreme Heat Training Material	Distributed to all VSCL personnel

VII) Standard Operating Procedures (SOP) for each Planned Task & Activity

Standard Operating Procedures (SOP) Identified:	Yes (attached in SOP)
Safe Work Practices (SWP) Identified:	Yes (attached in SOP)
Affected Personnel Trained on SOP's & SWP's:	Yes – all test team personnel will be trained in SOP and required to know its contents

Records will be kept of all VSCL personnel training.

VIII) Ultimate Disposal Plan

A detailed plan is required for the ultimate disposal of unused equipment, materials, chemicals and wastes following project conclusion; includes the plans for:

- *Clean up and decontamination of instrumentation, equipment & facilities,*
- *Laboratory decommissioning and closure,*
- *Waste Minimization,*
- *Pollution Prevention (P^2),*
- *Environmental Stewardship & sustainability*

There is not anticipated to be any unused materials or chemicals as a result of this program. All chemicals (fuel) will be consumed during the course of testing. In the event of fuel spill, the fuel will evaporate almost instantly. However, every effort will be made during fueling and de-fueling to prevent any fuel spillage through monitoring of fuel levels in the aircraft fuel tank. A small amount of fuel (~1cc) is spilled through the fuel tank overflow at the end of the fueling procedure.

All project operations will be planned and managed for environmental sustainability, waste minimization and pollution prevention, as well as health, safety and security. Following completion of this project, all materials and equipment will be evaluated for future productive use, wastes will be disposed in compliance with the university's Hazardous Waste Management Plan, and the facilities will be cleaned and decontaminated as necessary to return the space to safe and productive usage.

IX) List & attach all necessary Emergency Planning

Emergency Response Plan	See attached SOP and HAP.
Building Emergency Evacuation Plan	N/A
Emergency Contact Information (*ECI*)	Posted on door of Riverside Building 7046.
Spill Control Plan	N/A
Decontamination & Clean Up Plan	N/A

X) Internal Safety Reviews

Procedure for Periodic Internal Safety Audit & Review:

1. The PI or designee will inspect the laboratory weekly, document findings, and implement corrective action within 24-hr.
2. The Department's designated Safety Officer will conduct monthly inspections, document findings, and implement corrective action within 24-hr.
3. EHSD will conduct an annual laboratory safety inspection, issue a documented safety inspection report, and conduct follow up inspections to ensure prompt corrective action.
4. EHSD will conduct periodic shop safety inspections, issue a documented safety inspection report, and conduct follow up inspections to ensure prompt corrective action.

In addition to the above laboratory inspections, the Pegasus aircraft will be evaluated before and after each flight, and at least once a month in between flights, by the Test Director (Dr. Valasek) or a delegate thereof for airworthiness and operational safety. All vehicle inspections will be performed in accordance with the vehicle written procedures and instructions. Such vehicle inspections will be documented.

A safety review for the team prior to beginning of flight testing will be performed at the pre-flight briefing.

The Test Safety Officer will verify training is provided to pilot, ground handling and other personnel that may be present during test operations.

XI) NanoTechnology and Nanoscale Materials

All work with NanoTechnology and/or Nanoscale Materials must be conducted in accord with the TEES and Engineering "*Guideline for Working Safely with Nanotechnology, Nanoscale Materials & Particles.*" By submitting this PSA document I/we declare my/our commitment to comply with best practices and with all provisions of this Guideline in order to prevent potentially harmful exposures to nanoscale materials.

All Engineering projects involving the use ot nanotechnology and/or nanoscale materials must be conducted in accord with the Engineering Guideline for Working Safely with Nanotechnology and Nanoscale Materials." By signeture on this PSA document, the PI and all affected project personnel confirm they have read and are familiar with all provisions of the Guideline, and pledge to conduct all project operations in compliance with the Guideline and with current Best Practices as published by the National Insititute for Occupetional Satety & Health (NIOSH), the Occupational Safety & Health Administration (OSHA), and the U.S. Environmental Protection Agency (EPA)

NOTE: The Engineering Guideline for Working Safely with Nanotechnology and Nanoscale Materials is available on the Engineering SafetyNet web site at http://engineering.tamu.edu/safety/ , under "Guidelines."

XII) Commitment to a Safe, Healthful and Secure Workplace Environment

By submitting this PSA document I/we declare our commitment to full compliance with federal & state law, and with TAMU & TEES rules and requirements for a safe, healthtul, secure workplace environment, in support of our goal for safe and productive research outcomes.

XI) Safety Agreements

Location of Project Records & Files: 746B H.R. Bright Building

Signed By:

Principal Investigator

Researcher/Lab Technician

Graduate Student(s)

Student Worker(s)

Other...

XII) Attachment Section

Material Safety Data Sheet(s)
Chemical Inventory
Hazard Analysis Plan (HAP)
Standard Operating Procedures (SOP)